The Mats Pathfinder Navigation System

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Extended Abstract

Mission overview

Mars Pathfinder is one of a series of relatively small, simple missions comprising NASA's Discovery Program. The mission is primarily an engineering demonstration of key technologies and concepts for eventual use in future missions to Mars employing scientific landers, Mars Pathfinder also delivers a significant science payload to the surface of Mars, that performs investigations of the structure of the Martian atmosphere, surface meteorology, surface geology and morphology, and the elemental composition of Martian rocks and soil. In addition, a free-ranxillg surface rover is deployed to conduct technology related experiments, and to serve as an instrument deployment mechanism. Upon successful landing, the and other planets, solar radiation pressure and velocity changes from trajectory correction maneuvers ('TCM's) and attitude updates. The filter will also be used to estimate the errors caused by ground-based phenomena such as DSN station locations, Earth spin rate and spin axis orientation, ionosphere delay, and station-induced biases.

Once an update to the spacecraft's orbit is obtained, this information will be delivered to the Mars Pathfinder Flight Team for mission planning and sequencing purposes. This updated orbit is also used as the starting point for designing each of the four TCM's planned for cruise, as well as predicting the conditions for atmosphere entry.

Trajectory Correction Maneuvers

During the interplanetary cruise phase, a series of four trajectory correction maneuvers (TCMs) are performed to compensate for launch vehicle injection errors and navigation errors that have occurred. These TCM's are planned for Launch+30 days, Launch+60 days, Arrival-60 days and Arrival-10 days.

At injection from Earth orbit, the spacecraft will be targeted to a biased aimpoint to minimize the probability that the PAM-D booster stage will impact Mars. TCM-1 will undo most of this bias via a 'turn-and burn' maneuver, where the spacecraft turns to orient its spin axis in the direction of the required Delta-V and performs a continuous thruster burn. If the required attitude is along a direction that would violate thermal, communication or power constraints, the maneuver will consist of two turn-and-burn maneuvers (both along acceptable directions) that vectorally add to the correct Delta-V. TCM-1 will be the largest maneuver performed during the mission, accounting for approximately 90% of the total Delta-V. TCM-2 will be performed 30 days later, to correct orbit determination and maneuver execution errors from TCM-1.

TCM-3 will be the first maneuver to target directly to the aimpoint that will result in a landing at a predetermined location. Due to the increased distance from Earth to the spacecraft at this point in the mission, the spacecraft cannot turn its spin axis far from Earth and still maintain communication with Earth. Therefore, TCM-3 will be executed as a 'vector-mode' maneuver, whereby the spacecraft maintains an Earth-pointed attitude and the maneuver is performed as a series of thruster pulsings along the spacecraft's axial and lateral directions. TCM-4, which corrects errors from TCM-3, will be performed in a similar manner.

TCM-4 is expected to be the last maneuver prior to atmosphere entry. However, plans for a fifth maneuver will be made in the unlikely event of a large navigational error that would jeopardize the success of the mission. This fifth maneuver could be performed as late as 6 hours out without severely impacting the series of events required for entry, descent and landing.

Interplanetary navigation accuracy assessment

There are two requirements that drive the delivery accuracy for the navigation system. The first requirement states the error in the flight path angle will be no greater than 10 at the atmosphere entry point, which is reached at an altitude of 130 km. The second requirement is to deliver the lander to a predetermined location on Mars at 19.5° North latitude and 32.8° West longitude, with a downtrack error no greater than 150 km and a crosstrack error no greater than 50 km.

Covariance studies and Monte-Carlo analyses have been performed to determine the expected level of navigation accuracy that can be achieved. Inputs into this analysis include the magnitude of various spacecraft-based and ground-based error sources, tracking data

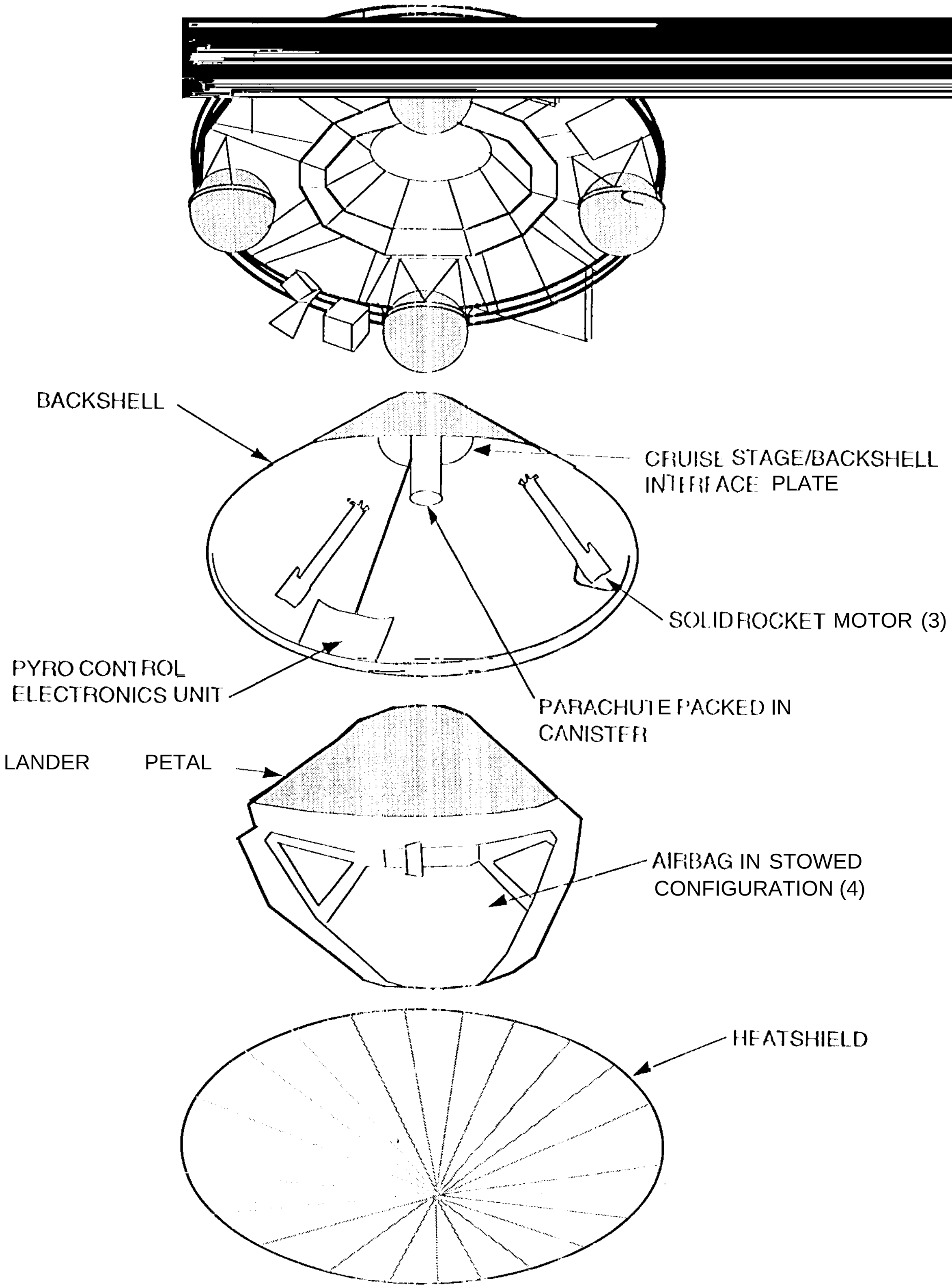

Figure 1: Exploded View of the Mars Pathfinder Flight System

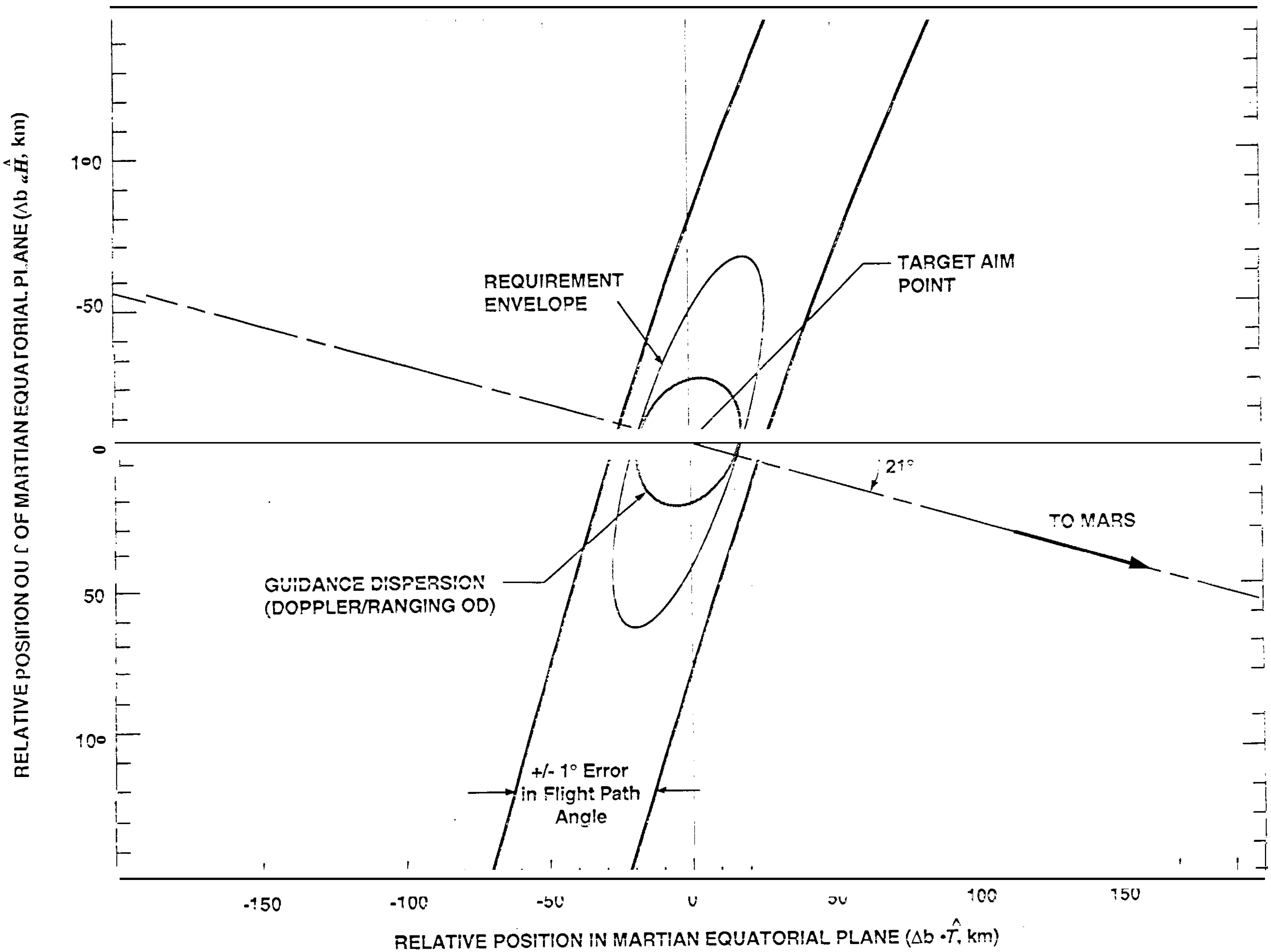

Figure 2: B-plane representation of Navigation Requirements and Capability